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By-Seibert, Warren F. Reid, Christopher J.

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Learning and retention may be influenced by subtle instructional stimulus characteristics and certain visual memory aptitudes. Ten stimulus characteristics were chosen for study; 50 sequences of programed instructional material were specially written to conform to sampled values of each stimulus characteristic. Seventy-three freshman subjects received the 50 sequences and then took an immediate and a delayed (one-week) posttest to assess learning. Measures on four visual memory and cognition aptitude factors were available for 43 of the subjects. By means of tear-down regression algorithms, the 10 stimulus characteristics were used to predict to the learning criteria. The ratio of examples within a sequence to the number of frames in the sequence had a correlation of about -.70 with both the immediate and delayed posttest. The inclusion of other variables did not increase the prediction significantly. Together, total frames and number of responses per frame predicted item difficulty on the posttest (multiple R to the second power=.90). Of the aptitude variables, Vocabulary aptitude and Short Term Object Memory tended to increase prediction to the delayed posttest criterion, while Serial Integration aptitude and Short Term Color Memory did not. (LS)

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FINAL REPORT
May 1968

Prepared by

Warren F. Seibert and J. Christopher Reid

AUDIO VISUAL CENTER
PURDUE UNIVERSITY – LAFAYETTE, INDIANA

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W.F.S
J.C.R.

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Purdue University
Lafayette, Indiana 47907

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INTRODUCTION

The present study is one of a series of continuing investigations of the effects of instructional stimulus characteristics in fostering learning and the retention of learning, and in the investigation of certain visual memory aptitudes as predictors of learning and retention.

Characteristics of Instructional Stimuli

Constructed responses, short steps, and knowledge of results are frequently cited as the salient characteristics of the instructional materials classed as programmed learning. However, additional characteristics may also affect learning to a considerable degree. These other characteristics include grammatical structure (Epstein, 1961, 1962; Coleman, 1965; Marks and Miller, 1964), the constraining effects of syntax (Aborn, Rubenstein and Sterling, 1957), and affixes and suffixes (Myers, 1964; O'Connor, 1950; Smith, 1965; Miller, 1951) to name a few. The influence of grammatical, syntactical and other stimulus characteristics on learning could be studied not only as they occur in programmed instructional materials but also as they occur in other varieties of instructional materials. The literature on some of these grammatical and syntactical characteristics of stimuli that may affect learning has been recently reviewed elsewhere (Myers, 1964; Smith and Seibert, 1966) and will not be repeated here, except to discuss briefly the two above-named studies as background for the present investigation. Although both limit their investigation to programmed instructional material, it is valuable to use their findings in generating hypotheses relevant to other instructional methods as well.

Myers (1964) sampled sequences of frames from the early portions of three programmed instruction texts and characterized each frame or sequence of frames in his sample in terms of 40 objective char-

acteristics, such as average number of words per frame, the Flesch reading ease index of sentences in the sequence, the number of initial (not review) learning frames in a sequence, etc. Each sequence (or series of instructional frames) taught one criterion behavior. In all, 99 criterion behaviors were represented in the instructional materials and in the related criterion test. Myers' Ss read the programmed instructional material, then took either the immediate or delayed (four-week interval) criterion posttest. A control group was not exposed to the programmed material, but took the criterion test. Using the item scores as a criterion vector, Myers determined which of the 40 vectors of frame characteristics predicted the criterion most efficiently by multiple regression techniques. Since five dependent variables were defined in the full study, five multiple regression analyses were run. The five dependent variables included immediate posttest item difficulties, delayed posttest item difficulties, and three measures of learning gain or loss. Myers found that only 25 of the 40 independent variables[1] appeared in any of the five multiple regression equations as finally determined by a "tear-down" method and only 13 of the 25 accounted for statistically significant increases of multiple Rs. All multiple regression models in this study (and in the Smith and Seibert study discussed below) were linear, first-order models, and assumed homogeniety of variance of the dependent vector. A typical equation involved sums and differences of vectors.

The emphasis in the present report will be on instructional stimulus characteristics, not response characteristics. However, Myers did find that a response mode variable (matching, multiple-choice, etc.) had a higher zero-order correlation with one of his dependent variables than did any other stimulus characteristic variable.

Smith and Seibert (1966) continued to study objectively-indexed

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[1] See Appendix A.

stimulus characteristics by having another group of Ss work through the Holland-Skinner program, The Analysis of Behavior. An 183-item constructed-response criterion test was adapted from Holland and Skinner's review sets and was administered both to treatment group Ss who studied the Holland-Skinner text and to control group Ss who did not study the text. For each of the 183 criterion test items, six criterion vectors were computed: immediate and delayed absolute gain score, immediate and delayed relative gain score, and immediate and delayed residual gain score. Smith and Seibert used 37 independent (predictor) variables, some of which were taken from the earlier Myers study. The authors chose to divide the 183 test items into halves randomly. The first half, with 91 items in the criterion vector, was called sample 1; the second half, with 92 items, was called sample 2. Twelve multiple regressions were performed, one for each of the halves for each of the six criterion vectors. Interestingly, the predictor variables retained in the six regression equations involving the three "immediate" and three "delayed" posttest criteria for sample 1 were generally the same. Also, the predictor variables retained in the other six regression equations (three "immediate" and three "delayed") for sample 2 were generally the same. However, the predictor variables of the six equations for sample 1 were generally quite different from those in the equations for sample 2. As would be expected from this dissimilarity, when the investigators sought to cross-validate the sample 1 and sample 2 equations, they achieved only limited success, either for the immediate or the delayed posttest data.

Of the thirty-seven independent variables, 18 appeared in the twelve multiple-regression equations determined in the study. These 18 are indicated in Appendix B.

In summary, although these two earlier studies have not been without methodological problems, their efforts are still of interest. In the Myers study, nine stimulus characteristic (or independent) variables gave a shrunken R of .66 with the criterion of immediate

posttest difficulty levels, and nine variables produced a shrunken R of .53 with a similar criterion based on delayed posttest scores. Five of these nine variables were the same in both regression equations, the sign of the beta coefficients of the five variables were identical in both, and the magnitude of the beta coefficients of the five were similar. Considering the similarity of the two criterion vectors (immediate and delayed posttest), these similarities between the two regression equations are not unexpected.

What is also interesting is that these objective instructional stimulus variables, typically ignored in other instructional research, produced the high multiple R's that they did. Although Smith and Seibert did not pursue the differences among their 183 criteria items, the mean of the shrunken multiple R's for the first item (and instructional sequence) sample was .46, and for the second sample was .56. These values typically occurred in regression equations having four or five independent vectors of stimulus characteristics.

Effectiveness of Visual Memory Aptitudes in Predicting Learning

A previous study by Seibert, Reid and Snow (1967) investigated the ability domains of audio and visual cognition and memory. Realizing that paper-and-pencil tests were not suited for measuring such abilities as motion perception and short term memory, they designed several tests in film form. A battery of 25 tests, some film, some paper-and-pencil, and one on slides, was administered to 159 university undergraduates. The correlation matrix of the 25 tests was analyzed by principal components, Kaiser image analysis (Kaiser, 1963; Reid, 1968), and Guttman image covariance analysis (Guttman, 1953; Reid, 1968). Each of the three resulting matrices of unrotated "factors" was rotated to a varimax criterion (Kaiser, 1959). Eight or nine rotated "factors" usually resulted. Although some differences were noted among these three solutions, generally

the rotated solutions agreed well, both in the particular variables defining a "factor" and in the relative magnitude of "loadings" on each "factor."

Forty-three of the 159 Ss in the Seibert, Reid and Snow study participated also in the present study. Nineteen of the 25 variables from that study were selected and correlated (see Tables 4 and 5) and principal components and Kaiser image analyses were executed. (For a description of the 19 tests, see Appendix C.) Seven components resulted after a varimax rotation of the components matrix, and six "factors" resulted after a varimax rotation of the scaled Kaiser image analysis matrix. The principal components solution, which appears in Table 6, was selected to obtain component scores (Kaiser, 1962; Reid and Urry, 1968) for each of the 43 Ss on each of the seven components.

The seven components or "factors" may be described as follows: the first is described by the Gestalt Completion test, Successive Perception III and Successive Perception IV, Picture Identification, Position Recall II, and the viewing distance "marker" variable. This is the stable Serial Integration component, which appeared in earlier studies (Seibert, Reid and Snow, 1967; Seibert and Snow, 1965.) The ability identified here apparently involves rapid reception of temporally-spaced stimuli, their organization into meaningful whole cognitions, and possibly their verbal labelling. The second component is dominated by the two Short Term Color Memory tests. The Position Recall I test and two paper-and-pencil tests, Color Form Recognition and First and Last Names, comprise the third component. This component is also stable, having been found in earlier local studies (Seibert, Reid and Snow, 1967; Seibert and Snow, 1965.) It is at least similar to the Associative Memory factor described by French, Ekstrom and Price (1963, pp. 22-23.) The fourth component is clearly defined by the two vocabulary tests, Advanced Vocabulary and Wide Range Vocabulary, and no others. The highest coefficients on the fifth component are the two span tests: Digit Span Visual and Picture Memory Span. Other coefficients in this vector that

deserve some discussion are those of viewing distance (distance from the projection screen) and First and Last Names. Neither one of these coefficients is inconsistent with the interpretation of this component as span ability. The last two components are defined by the Short Term Object Memory and Short Term Visual Memory tests, respectively. In summary, then, the entire rotated component matrix is quite like the rotated component matrix of the larger matrix of 25 variables in the Seibert, Reid and Snow study, with the exception of the current partictioning of the Short Term Memory vector found in the analysis of the larger matrix into Short Term Color, Object, and Memory vectors.

PROBLEM

The present study has two purposes. The first is to estimate the effectiveness of certain grammatical, syntactical, and other characteristics of instructional stimulus material in predicting learning. This purpose could be rephrased as asking what proportion of the variance of a learning criterion could be accounted for by selected characteristics of the stimulus material. The ten characteristics selected for study appear in Table 1. These ten characteristics can be thought of as ten column vectors, each having a dimension equal to the number of sequences in the learning criterion vector. The ith element of each column indicates the value of that particular characteristic for the ith sequence. If the ten column vectors are thought of as a matrix, then the ith row specifies the particular value of each of the ten characteristics for the ith instructional sequence. After the matrix of numerical values of specifications was generated, then each instructional sequence was written in accordance with these specifications.

A subset of the ten independent vectors was selected by a multiple regression tear-down algorithm to predict to three learning criteria: immediate posttest, delayed (one-week) posttest, and item difficulty.

The second purpose of the study was to see if any of the visual memory abilities, as measured by several recently-developed film tests, would be effective in predicting learning or retention of the instructional material. Rather than using several vectors of Ss' scores on the several film tests to predict each learning criterion, information from the principal components solution was utilized. From the seven component, 19 variable matrix mentioned above, a matrix of component scores was generated (Kaiser, 1962; Reid and Urry, 1968). This procedure in effect combined several relevant test score vectors into a particular component, and thus reduced the number of vectors used in regression analyses from the number of film

TABLE 1

ID# in Smith-Seibert Report	Title	Variable characteristics occurring in Holland and Skinner			Variable characteristics after distribution generation & constraints	
		Mean	Sigma	SE	Mean	Sigma
1	Total frames	9.70	7.30	.534	10.48	2.84
3	Review frames	3.99	4.34	.354	4.10	1.27
7	Key term as response	4.30	4.47	.327	4.68	1.46
12	Maximum words/frame	34.64	5.46	.399	37.58	9.28
21	Percent of responses occurring in first third of frame	.05	.11	.008	2.14	1.01
22	Intentional sets	1.93	1.32	.097	1.86	.61
27	Application frames	.60	.30	.022	.58	.18
31	Number of responses/frame	1.44	.34	.025	1.45	.29
37	Words/sentence	18.13	4.07	.298	17.50	3.81
26	Sentences/frame	1.44	.32	.234	1.47	.35

tests to the number of components. Of the seven components, four were selected for investigation in this study. They are serial integration, short term color memory, vocabulary, and short term object memory.

Accompanying this second purpose was the investigation of aptitude and stimulus interactions. The aptitudes considered were those defined by certain selected film tests, and the stimulus treatments considered were the ten characteristics of the instructional stimulus material.

PROCEDURE

Construction of the Program

Ten independent variables that showed predictive promise in the earlier Smith and Seibert study were selected for further study. These ten, which were characteristics of the instructional sequences in the Holland-Skinner program, The Analysis of Behavior (1961), are named in Table 1. The Holland-Skinner text was analyzed in the Smith and Seibert study (1966) to determine the means and standard deviations of the ten selected stimulus variables. Once these parameters were known, then new distributions were generated[1] having approximately the same mean and standard deviation (see Table 1.) One value was then randomly sampled from each of the ten distributions. The resulting row vector, having ten elements, thus specified ten constraints which a particular sequence of instructional material had to satisfy. A sequence of material was then written out, satisfying the ten constraints. This process was repeated, until fifty sequences had been written. The fifty sequences followed the content of the Holland-Skinner text as much as possible.

A short note about the sampling procedure may be of interest. To generate ten characteristics which would define the ith instructional sequence, a value was randomly sampled from each of the ten distributions. For example, for one sequence of the specially-constructed program, the value sampled from the Number of Total Frames distribution was 12, the value sampled from the Number of Review Frames distribution was 3, and so forth for the other 8 characteristics. Thus, the row vector indicating the constraints, or characteristics for this particular sequence was [12, 3, ...]. The sequence of specially-written frames that satisfied this particular

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[1]By design, the computer-generated distributions were quasi-normal, whereas many of the distributions of the 10 variables as they actually occurred in Holland-Skinner were skewed.

sampling from the ten distributions had a total of 12 frames, three of which were review frames. After each sampling from the ten distributions, six constraints or mathematical relationships were applied. One relationship was that the number of review frames obviously could not be greater than the number of total frames in that sequence. An example of the effect of this relationship on the sampling procedure follows. In the sampling for one sequence, the value of the Number of Total Frames variable selected was 2, and for the same sequence, the value of the Number of Review Frames variable selected was 4. Of course a sequence of frames could not have more review frames than there were frames in the entire sequence. To adjust this, the number of sigma units that a sampled variable departed from its mean was compared with the number of sigma units of the other variable from its mean. Since the sampled value of 4 of the Number of Total Frames variable was 2.3 sigma units from its mean whereas the sampled value of 2 of the Number of Review Frames variable was only .05 sigma units from its mean, another value was drawn for the Number of Total Frames variable.

Once the specifications for all sequences of frames had been computed, instructional material was written that satisfied these specifications. As stated earlier, generally the instructional material followed the content of Holland and Skinner (1961) as far as possible.

After the frames comprising each sequence were written, they were individually photographed onto 35 mm filmstrips. The stimulus question appeared in the upper half of the frame, and the correct or alternate responses appeared in the lower half of the frame. The 35 mm filmstrips were used in DuKane Redi-Tutor "teaching machines" that were specially modified mechanically for this study. The Ss studied each of the 50 sequences by reading the stimulus material on the upper half of the frame, writing out the answer on a separate answer sheet, advancing the filmstrip half a frame so that both the stimulus material and the correct answer appeared on the screen,

and comparing the correct answer with the answer they had written.

Subjects

The 73 Ss were second-semester freshman volunteers, 47 females and 26 males. Their mean grade-point average for the first semester had been 4.46 with a range of 2.46 to 5.78. (Two is an F, four is a C, and 6 is an A.)

All Ss were taught how to use the teaching machine, and they all worked a practice filmstrip of biology material 20 frames long to become acquainted with the method of presenting linear programmed instruction on the teaching machine.

All Ss worked at their own pace, and most Ss finished the 50 sequences in three or four separate sittings for a total of about 6 hours.

Forty-three of the 73 Ss had been paid participants in an earlier study (Seibert, Reid and Snow, 1967). This subset of 43 Ss, along with 116 other Ss unique to the Seibert, Reid and Snow study, had previously taken 16 filmed test of intelligence, and seven paper-and pencil tests. Two other variables, viewing distance and viewing angle were also included in the analysis.[1]

Criterion Tests

Each of the 73 Ss upon completion of the 50 sequences presented on the teaching machine immediately took a 50-item criterion test. One item tested the Ss' knowledge of each sequence. One week later the Ss took the same criterion test again. The criterion test was also presented on the teaching machine, each answer requiring a con-

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[1]The twenty-five variables and their intercorrelation matrix, rounded to two places, appear in Appendixes B and C of Seibert, Reid and Snow (1967).

structed response, just as the stimulus instructional material had required.

In addition to the immediate and the delayed criterion posttests, item difficulties for each item were obtained for each sequence.

RESULTS

Constructed Program

Means and standard deviations of the ten variables that governed the construction and the writing of the instructional programmed stimulus frames are given in Table 1. The data on the three left-hand columns in Table 1 are based on an N of 183 sequences. The data on the two right columns in Table 1 are based on an N of 50 sequences.

Means and standard deviations of the two 50-item posttests and of the item difficulties for the 50 sequences were:

	Mean	Standard deviation
Posttest 1	42.76	20.42
Posttest 2	38.50	20.35
Item difficulty	850.72	288.41

Thus some loss in retention occurred during the week between the administration of posttest 1 and posttest 2, as expected.

Effectiveness of Objective Characteristics to Predict Learning

The first purpose of the study was to determine if the three sequence learning criteria (immediate posttest, delayed posttest, and item difficulty) could each be expressed as a composite of a reduced number of the ten predictor variables listed in Table 1. (The intercorrelation matrix of these, the ten predictor variables and the three criteria variables, appears in Appendix D.)

Initially, three separate regression models were analyzed. Each of the three was an unweighted, linear, first-order model, having ten sequence characteristics predicting to one of the three learning criteria vectors. The regression algorithm followed was a tear-down

procedure. The predictor variable in the model with the lowest probability was compared against a fixed probability level, and if less than the fixed level, was dropped from the model. The program used was the Weighted Regression Analysis Program (WRAP) written by M. Dale Fimple of the Sandia Corporation.

All vectors were of dimension 50, the number of sequences. The ith element in the vectors represented the ith sampling from the generated distributions whose means and standard deviations appear in Table 1. The dimension of the vectors was small because of the labor and care required to write each sequence within the generated specifications.

The results of the three initial regression analyses appear in Table 2. The first two equations in Table 2 in effect simply reflect the correlation of the Application Frames variable[1] with the criterion vector. The third equation indicates that excellent prediction to the item difficulty vector may be obtained with the Total Frames and the Number of Responses per Frame variables.

All residuals for the three regression equations were plotted against the fitted dependent and independent variables and were inspected for anomalies. From an examination of residuals, it was thought that a better fit might obtain if a weighted regression analysis were done. Of those weighted models that were tried, the weighting by the inverse of the square of the Applications Frame variable resulted in the best prediction for the criteria of immediate and delayed post-test. Examination of residuals from these weighted models indicated that the models were satisfactory. The results of these weighted regressions appear in Table 3.

Again, the equations in Table 3 merely reflect the correlation of the Application Frames variable with its respective criterion. Including other vectors in the prediction scheme did not greatly increase the size of the multiple correlation.

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[1]See Appendix E

TABLE 2

Unweighted Regression Analyses

Immediate Posttest Criterion

$R = .30$

$R^2 = .09$

$Y = 62.01 - 33.40{*}AF$

Delayed Posttest Criterion

$R = .20$

$R^2 = .08$

$Y = 56.40 - 31.06{*}AF$

Item Difficulty Criterion

$R = .95$

$R^2 = .90$

$Y = -829.09 + 81.53{*}TF + 570.76{*}NRP$

AF = Application Frames variable

TF = Total Frames variable

NRP = Number of Responses/Frame variable

An asterisk denotes the product of a constant times a variable.

TABLE 3

Weighted Regression Analyses

Immediate Posttest Criterion

$R = .69$

$R^2 = .48$

$Y = 75.40 - 58.40*AF$

Delayed Posttest Criterion

$R = .73$

$R^2 = .53$

$Y = 74.48 - 64.83*AF$

AF = Application Frames variable

The variable of Application Frames, the ratio of application frames to total frames in the sequence, accounted for about half of the unadjusted variance of the immediate and delayed posttest criteria in the weighted regression analysis. Its contribution is achieved by subtracting the weighted Application Frames vector from the weighted unit vector.

Two other independent variables, Total Frames (the number of total frames in a sequence) and Number of Responses per Frame, predicted in a positive sense to the item difficulty dependent variable in the unweighted regression analysis. These two independent variables accounted for ninety percent of the unadjusted variance of the item difficulty dependent variable. The weighted Total Frames and Number of Responses per Frame variables are added to the weighted unit vector to achieve this prediction. This is in harmony with the principle that material is learned better if more time is spent studying it, and that greater learner participation increases learning.

It is to be expected that the regression analyses for the immediate and delayed posttest criteria are similar, since the dependent variables in each instance are similar. The application frame variable plays no role in predicting the item difficulty criterion; in the tear-down algorithm it is the third variable omitted (out of 10). The two variables which give excellent prediction to the item difficulty criterion, Total Frames and Number of Responses per Frame, have zero-order correlations with the criterion of .76 and .51, respectively. Conversely, the Total Frames and Number of Responses per Frame variables play almost no role in predicting to the posttest dependent variables.

One unusual characteristic of the instructional stimulus material might be noted. The posttest item that tested Ss' knowledge of the sequence teaching differential reinforcement was quite difficult; no S got it correct.

Effectiveness of Visual Memory Aptitudes to Predict Learning

Forty-three of the 73 Ss who worked with the programmed instructional materials also took a battery of film tests to measure visual

TABLE 4

Variable Number	Name	Mean	Standard Deviations
1	First and Last Names	23.00	6.02
2	Visual Number Span	11.33	3.36
3	Gestalt Completion	17.09	2.88
4	Viewing Distance	5.22	1.43
5	STCM I	34.56	8.02
6	STOM II	40.05	5.40
7	STCM II	38.16	5.75
8	STOM I	32.14	6.48
9	Successive Perception III	9.16	3.48
10	Picture Identification	8.67	2.81
11	Successive Perception IV	3.93	3.05
12	Picture Memory Span	67.70	15.41
13	STVM II	28.42	8.73
14	STVM III	40.12	10.53
15	Position Recall I	34.58	8.32
16	Position Recall II	23.37	4.48
17	Wide Range Vocabulary	27.67	5.05
18	Advanced Vocabulary	17.35	4.06
19	Color Form Recognition	23.53	4.59

TABLE 5

Intercorrelation Matrix of Nineteen Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	.16																	
3	-.05	.12																
4	.03	.12	-.06															
5	.18	.13	.19	.04														
6	.14	.06	.31	.03	.53													
7	.06	.12	.17	-.18	.56	.47												
8	.10	.11	.33	.00	.53	.64	.38											
9	-.01	-.08	.43	-.30	.17	.27	.28	.27										
10	.03	.01	.38	-.34	.06	.20	.19	.16	.55									
11	.03	-.05	.40	-.34	.19	.27	.33	.20	.63	.61								
12	.24	.53	.07	.08	.17	.03	.06	.03	-.05	-.01	-.05							
13	.12	.00	.18	-.22	.38	.56	.35	.44	.36	.50	.34	.09						
14	.12	-.01	.14	-.22	.33	.52	.34	.39	.35	.44	.40	-.02	.76					
15	.41	.10	.00	.06	.10	.14	.03	.20	.06	.09	.12	.08	.14	.19				
16	.25	.04	.03	-.05	-.06	.04	.06	.04	.20	.19	.06	.08	.14	.04	.33			
17	.04	.24	.13	.07	.03	.08	-.00	-.03	-.08	.01	.02	.10	-.07	.00	-.05	.06		
18	.07	.23	.19	.05	.05	.18	.01	.07	-.04	.06	-.00	.08	.05	.11	.03	.00	.66	
19	.38	.07	.02	.01	.15	.11	.13	.09	.12	-.04	.13	.11	-.02	.07	.35	.21	.00	-.01

TABLE 6

Variable	Orthogonally - Rotated Component Matrix						
1	.08	-.34	-.54	-.12	-.49	-.18	.03
2	-.01	.03	-.13	.29	-.82	-.06	-.03
3	.86	.11	-.03	.16	-.11	-.30	-.03
4	-.60	.06	-.15	.15	-.42	-.16	-.20
5	-.07	-.84	.09	-.04	-.14	-.33	.04
6	.03	-.27	-.03	.20	-.11	-.77	.31
7	.17	-.85	-.03	.14	-.03	-.06	.12
8	.09	-.11	-.02	-.00	-.01	-.91	.08
9	.82	-.16	-.10	-.11	.03	-.07	.19
10	.63	.08	.10	.17	-.10	.00	.53
11	.64	-.20	-.27	-.04	.08	.01	.42
12	-.02	-.17	.06	-.05	-.86	-.00	.18
13	.11	-.13	.10	-.03	-.11	-.24	.87
14	.19	-.04	-.14	.19	-.01	-.11	.85
15	.03	.27	-.87	.14	.07	-.08	.14
16	.53	-.02	-.30	.25	-.05	.15	-.29
17	-.01	-.23	-.06	.89	-.08	-.00	-.04
18	.10	.15	.03	.81	-.10	-.16	.26
19	.25	-.31	-.58	-.10	-.27	.19	-.23

cognition and memory. Nineteen of these tests were analyzed by a principal component analysis and seven components (associated with eigenvalues greater than 1) were orthogonally rotated. Seven component scores for each of the 43 Ss were found and certain of these component scores of visual memory aptitudes were included in an analysis to predict learning.

As noted earlier, two of the objective stimulus characteristic vectors, Total Frames and Number of Responses per Frame, predicted successfully to an item difficulty criterion. The mean and the standard deviation of each of these two vectors was determined, and the former vector was divided into three vectors of dimension 43 of high, medium, and low Total Frames per sequence, depending upon the number of sigma units the sampled value of any given sequence departed from its mean, and the Responses per Frame vector was divided into two vectors of high Responses per Frame and low Responses per Frame.

These five vectors were included in a regression analysis with those four of the seven component score vectors that represented Serial Integration, Short Term Color Memory, Vocabulary and Short Term Visual Memory. These nine independent variables were used in three separate regression analyses to predict to the three criteria (immediate and delayed posttest, and item difficulty.) The vocabulary vector was chosen to compare with the three visual memory vectors.

For these three analyses, a tear-down regression algorithm was not used. Instead, each of the five objective characteristic vectors was combined in turn with one of the four aptitude vectors to see if the two vectors would predict to the criterion vector significantly better than the objective characteristic vector alone. This can be stated alternatively as testing to see if the coefficient of the aptitude vector is zero (Bottenberg and Ward, 1963).[2]

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[2] The authors express their appreciation for the advice of Dr. Robert A. Bottenberg. The faults of the present study, however, are solely the responsibility of the authors.

The program used for this analysis was the Persub system by Ward, Hall, and Buchhorn (1967). A similar procedure was followed for all three criteria vectors.

For the immediate posttest criterion, none of the four aptitude vectors significantly increased prediction except the vocabulary vector. The effect of including the Vocabulary (Vocab) aptitude vector with the Total Frame high, medium, or low (TF-H, TF-M, TF-L) or with the Responses per Frame high or low (RPF-H, RPF-L) vectors is shown in Table 7.

TABLE 7

Immediate Posttest Criterion Probability that Coefficient of Vocabulary Vector is Zero

Full Model	R^2	Restricted Model	R^2	p
Vocab & TF-H	.45	TF-H	.35	.01
Vocab & TF-M	.38	TF-M	.27	.01
Vocab & TF-L	.39	TF-L	.29	.01
Vocab & RPF-H	.41	RPF-H	.32	.02
Vocab & RPF-L	.40	RPF-L	.30	.01

For the delayed posttest criterion, the probability was small that the coefficients of two of the aptitude vectors were zero. These two vectors were the Vocabulary vector and the Short Term Object Memory Vector. These results are shown in Table 8. The levels of significance for the Short Term Object Memory Vector are not startling, but they are certainly of interest.

For the item difficulty criterion, generally none of the aptitude vectors increased prediction significantly when included in the regression equation.

TABLE 8

Delayed Posttest Criterion

Probability that Coefficient of Vocabulary Vector is Zero

Full Model	R^2	Restricted Model	R^2	p
Vocab & TF-H	.47	TF-H	.37	.01
Vocab & TF-M	.39	TF-M	.27	.01
Vocab & TF-L	.43	TF-L	.32	.01
Vocab & RPF-H	.43	RPF-H	.33	.01
Vocab & RPF-L	.42	RPF-L	.32	.01

Delayed Posttest Criterion

Probability that Coefficient of STOM Vector is Zero

Full Model	R^2	Restricted Model	R^2	p
STOM & TF-H	.41	TF-H	.37	.11
STOM & TF-M	.32	TF-M	.27	.10
STOM & TF-L	.36	TF-L	.32	.14
STOM & RPF-H	.38	RPF-H	.33	.08
STOM & RPF-L	.36	RPF-L	.32	.13

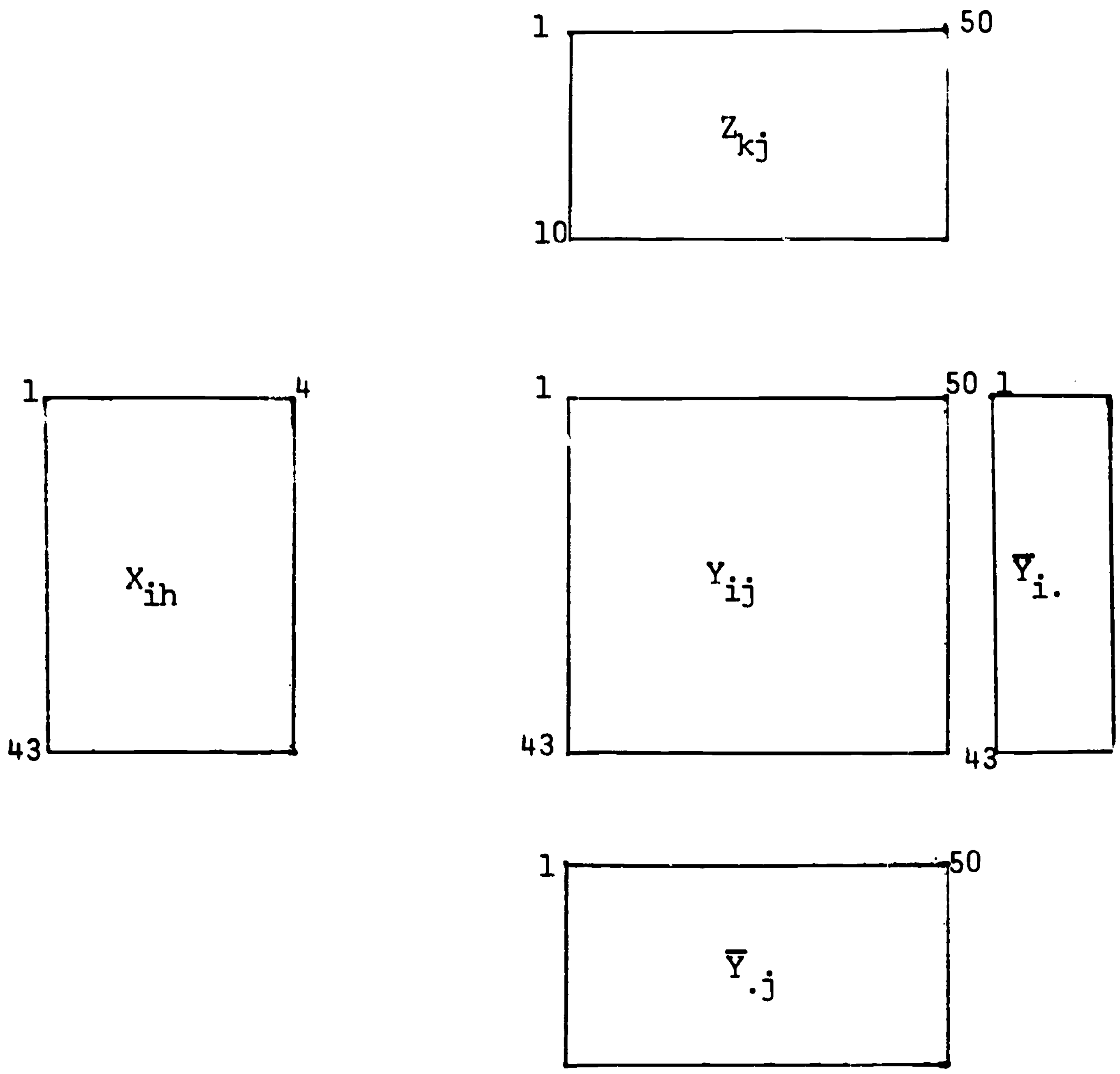
The final phase in the study of using visual memory aptitudes to predict learning was the investigation of interaction between Ss' aptitudes and types of stimulus treatments

For this interaction analysis three matrices were utilized. The first matrix was the 43 x 4 subjects by aptitude matrix, labeled X_{ih} in Figure 1. The second matrix was the 43 x 50 subjects by

The interaction methodology was designed by Dr. David Wiley of the University of Chicago, and is described in Seibert and Snow (1965a),

FIGURE 1

SCHEMATIC REPRESENTATION OF THE INTERACTION ANALYSIS



frame sequences matrix, labeled Y_{ij} in Figure 1. The third matrix was the 10 x 50 treatment by sequences matrix, labeled Z_{kj} in Figure 1. The X_{ih} matrix contains four column vectors of orthogonal component scores. The Y_{ij} matrix contains 43 row vectors of Ss' scores on each of the 50 sequences, or alternatively, contains 50 column vectors of item difficulties. The Y_{ij} matrix can be the matrix of Ss' scores on the immediate posttest, the delayed posttest, or the item difficulty matrix. The Z_{kj} matrix contains 50 column vectors of ten objective stimulus characteristics describing each of the 50 sequences. The two vectors $\bar{Y}_{i.}$ and $\bar{Y}_{.j}$ are row mean and column mean vectors respectively of the Y_{ij} matrix.

Main effects were subtracted from the Y_{ij} criterion matrix by the equation:

$$E_{ij} = Y_{ij} - \hat{\bar{Y}}_{i.} - \hat{\bar{Y}}_{.j} + \bar{Y}_{..}$$

where $\bar{Y}_{..}$ is the grand mean of the matrix Y_{ij} . The residual E_{ij} matrix represented either error variance or aptitude x treatment interaction variance, or both. If the e_{ij} are represented as a single vector e_t where $t = i \times j = 43 \times 50 = 2150$, then the e_{ij} may be thought of as a criterion vector of dimension 2150 in a prediction equation. The $i \times h$ X matrix and the $k \times j$ Z matrix were used to generate the $h \times k = 4 \times 10 = 40$ predictor variables for each of the 2150 observations. For each S (i) , each aptitude (h) was multiplied by each treatment (k) .

A constant was added to each element of the X_{ih} matrix before multiplying the x_{ih} times the z_{kj} to determine the 40 predictor variables.

The results of the interaction analysis using a linear, first-order unweighted regression model indicated that with a tear-down algorithm, none of the 40 independent variables predicted significantly to the residualized criterion vector. With all 40 variables the multiple $\underline{R}^2$ was only .14.

CONCLUSIONS

The present study had two main purposes: the first was to investigate the effectiveness of certain objectively-assessed instructional stimulus material in predicting a learning criterion, and the second was to investigate the effectiveness of visual memory aptitudes in predicting learning.

Ten objective stimulus characteristics were selected, and distributions of values were created for each of the ten stimulus characteristics. Fifty sequences of programmed instructional material were specially written to conform to sampled values of each of the ten characteristics. These 50 sequences were administered to 73 Ss, who took an immediate and delayed 50-item posttest, to assess learning for each of the 50 sequences.

Seibert and Snow (1965) and Seibert, Reid and Snow (1967) had identified certain visual memory and cognition aptitude factors, and measures on these aptitude factors were available for 43 of the 73 Ss.

Using tear-down regression algorithms, the ten stimulus characteristic variables were used to predict to the learning criteria. The Application Frames variable, the ratio of applications, illustrations, or examples within a sequence to the number of frames in the sequence, had a zero-order correlation with both the immediate and delayed posttest criteria of about -.70. The inclusion of other variables did not increase the prediction significantly. The Total Frames and Number of Responses per Frame variables together predicted the item difficulty criterion quite well, resulting in a multiple R^2 of .90.

The contribution of the Total Frames variable indicates that sequences with more frames were easier than those with

fewer frames, and the contribution of the Responses per Frame variable indicates that sequences permitting Ss to respond more frequently were easier than sequences that permitted Ss to respond less frequently. The relatively high negative zero-order correlation of the Application Frames variable permits the conclusion that the greater the ratio of applications or illustrations to total frames in a sequence, the more difficult was the criterion item for that sequence. It could be that when a relatively large amount of space was devoted to examples, Ss tended to learn those examples or illustrations, and failed to grasp the principle.

Probably most interesting of all was the fact that these objectively-determined characteristics of instructional stimuli, often overlooked in instructional research, predicted learning or item difficulty as well as they did.

For 43 of the 73 Ss, four measures of visual cognition and memory aptitudes were included in a regression analysis with variables of high, and low total frames in a sequence, and high review frames and low review frames. The four visual cognition and memory aptitudes included in the present study were Serial Integration, Short Term Color Memory, Vocabulary, and Short Term Object Memory. The Vocabulary aptitude variable was included mainly as a basis of comparison with the other three aptitudes. Each of these four aptitude variables was paired in turn with one of the total frames or review frames variables to determine if the coefficient of the aptitude variable was significantly different from zero. When compared against the alternative of predicting the immediate or delayed posttest criterion with one of the total frames or review frames variables alone, the Vocabulary variable generally had a probability of .01 that its coefficient was zero in the two variable model. No surprise was created by the finding that a measure of vocabulary aptitude combined with a total frames or review frames variable increased the prediction to a learning criterion. More interesting was the finding that the Short Term Object Memory variable also

tended to increase prediction to a delayed posttest criterion when the STOM variable was included with a total frames or review frames variable. Of equal interest was the result that the stable Serial Integration aptitude variable did <u>not</u> result in any increase in prediction to a learning criterion when it was included with a total frames or review frames variable.

It is anticipated in future research that some of the other visual memory and cognition aptitude measures that were not included in the present investigation will be studied in regression models, and that the four aptitude measures that were included in the present investigation will be studied in combination with other treatment variables.

Following an interaction analysis pattern outlined by David Wiley, an aptitude by treatment interaction study was conducted. A subjects by aptitudes matrix, subjects by sequence scores matrix, and a stimulus treatments by sequences matrix were utilized in this interaction analysis. Forty independent variables were the result of all possible combinations of aptitudes and objective stimulus treatments, and these forty variables predicted to a residualized subjects' sequence scores variable. The variance accounted for by the full set of independent variables was very low and none of the zero order correlations between the independent variables with the dependent variable were high. Whatever aptitude by treatment interaction may have existed was not detected by the interaction analysis used.

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APPFNDIX A

Twenty-Five of Forty Independent Variables in Myers (1964)

	Title	Description
1	total frames	total number of frames in a sequence
2	initial learning frames	total number of frames in a sequence which are provided for initial learning of the criterion behavior
3	review frames	total number of frames in a sequence which are provided for review of the criterion behavior
4	sentences per frame	average number of sentences per frame in a sequence
5	words per frame	average number of words per frame in a sequence
6	affixes/words	total number of affixes in a sequence divided by the total number of words in a sequence
7	Flesch R. E.	the Flesch "reading ease" index of a sequence
8	program rate	the average rate (expressed in frames per hour) at which a program was responded to by the Ss.
9	key word as stimulus	total number of times the key word, phrase, or concept appears as a printed stimulus in a sequence
10	key word as a response	total number of times the key word, phrase, or concept is required as a response in a sequence
11	concepts per sequence	total number of new and different ideas, terms, or concepts which are contained within a sequence where these terms are considered as new material introduced within the program
12	distributed review	the use of frames separated from initial learning frames and/or previous review frames by more than five frames
13	response mode	the response mode (constructed vs. selected) of the frames in a sequence
14	augmenting frames	total number of frames in a sequence which supply new information but do not require relevant responses

15	interlocking frames	total number of frames in a sequence which require review of an established criterion behavior while new information is being presented
16	rote-review frames	total number of frames in a sequence which present a problem identical to one presented earlier
17	delayed-review frames	total number of frames in a sequence which allow for distribution of practice of a criterion behavior
18	generalizing frames	total number of frames in a sequence which summarize points relevant to the criterion behavior
19	specifying frames	total number of frames in a sequence which exemplify a general rule or principle
20	copying frames	total number of frames in a sequence which provide the S with a model of the required response
21	whole/partial prompts	the ratio of whole prompts to partial prompts presented in a sequence
22	thematic prompts	total number of prompts in a sequence which depend upon previous associations to provide the necessary stimulus
23	response ideational	a measure of the complexity of the response ideational content for sequence
24	task set	the use of establishment of task set or the use of organizing material in a sequence to indicate a meaningful relationship of what is to be learned
25	rote-conceptual sequences	the use of rote or conceptual sequences

APPENDIX B

Eighteen of Thirty-Seven Independent Variables in Smith and Seibert (1966)

1. Alternatives Accepted: The number of alternative answers accepted as correct for the criterion test item.

2. Maximum Syllables per Frame: The number of syllables contained in the frame with the most syllables.

3. Prepositional Phrases per Sentence: The number of prepositional phrases per sentence within a frame sequence.

4. Complete Program Order: The rank order in which the initial learning frames first appear in the program, regardless of their relation to the immediate posttest.

5. Intentional Sets: The total number of sets containing frames intended to teach the key term.

6. Number of Responses per Frame: The number of responses per frame within a frame sequence. A multi-word response was considered as one response.

7. Vehicular Sets: The number of sets containing frames which incidentally present the key term as part of the contextual material intended to instruct another key term.

8. Vehicular Uses of Key Term: The number of frames which incidentally present the key term as part of the contextual material intended to instruct another key term.

9. Key Term as Response: The number of times that the frame sequence requires the learner to supply the key term wholly or in large part.

10 Formal Prompts: The total number of cues within a frame sequence regarding the form or appearance of a response. In this program, formal prompts were of three types: (a) the symbol (TT) indicating that the desired response is a "technical term," (b)

two answer blanks indicating that the desired response consists of two words, and (c) a partial spelling of the response indicating that the learner should complete the spelling of the desired response.

11. Letters in Key Term: The number of letters in the key term.

12. Words per Sentence: The number of words per sentence within a frame sequence.

13. Rules p. r Frame: The ratio of rules, generalizations, conclusions within a frame sequence ot the number of frames.

14. Concrete Noun Ratio: Ratio of concrete nouns to the total number of nouns within a frame sequence. A concrete noun is any noun referring to an object that can be photographed.

15. Maximum Cloze Score: The highest cloze score obtained by a frame in the frame sequence.

16. Cloze Score: A measure of reading ease. The procedure consists of (1) deleting every nth word (in this case, every 5th word) from the text, (2) replacing each word with a blank of standard size, (3) asking 15 Ss, not involved in the main part of the study, to fill in the missing blanks, (4) counting up the correct insertions, and (5) comparing the percentage of correct replacements among the various frame sequences. Synonyms were scored as incorrect with the exception that the words "reflex" and "respondent" were considered interchangeable. Mis-spellings were accepted if it was apparent that the S was attempting to write the correct answer.

17. Minimum Cloze Score: The lowest cloze score obtained by a frame in the frame sequence.

18. Affixed Word Ratio: Ratio of suffixes and prefixes to the total number of words within a frame sequence.

APPENDIX C

1. First and Last Names: A printed test of ability to learn first and last names. In each of the two parts of the test, S studies a page of 15 full names, first and last. He then turns the page to find a list of the last names only. He must record the first names associated with each last name (French, Ekstrom, and Price, 1963, p. 23).

2. Digit Span-Visual: Each of the 24 items in this projected slide test presents a series of digits; the series may range from four to thirteen digits. Each slide (i.e., each digit) appears for one second, with one-half second separating adjacent digits. At the close of each series, a slide says "Begin". The Ss are given 12 seconds to respond to each item and they must record the digits in the same order as presented. The test is a minor adaptation of the digit span test described by French, Ekstrom, and Price (1963, p. 27).

3. Gestalt Completion: This printed test presents ten items in each of its two parts. Each item presents a partial drawing of an object. Sections of each drawing have been deleted to make recognition of the object difficult. The Ss are to record the name of each object. The test is described in French, Ekstrom, and Price (1963, p. 11).

4. Viewing Distance: The distance is feet between the projection screen center and each S's randomly assigned seating position was determined.

5. Short Term Color Memory I: The Ss are first shown a stimulus pool of nine hexagonal color chips (a red, green, purple, yellow, orange, brown, gray, pink, and blue). After these are presented and named, the 54 items of the test then present the color chips in a 2 by 3 array, holding the array on the screen either for the duration of 4, 8, or 12 frames. There are, thus, three 18 item subtests, each with a different stimulus exposure duration.

In each item, after the array disappears, there are two blank film frames, then an empty hexagonal marker appears in one of the array positions. The Ss are to indicate the color which occupied the marked array position.

6. Short Term Object Memory II: The film test includes 54 items, the same stimulus pool of nine common object photographs, and three subtests distinguished as are subtests in variable 8. However, in each item of this test, after the array disappears, there are two blank frames, then one of the photographs appears again, centered on the screen. The Ss mark on their answer sheet the position occupied by the pictured object.

7. Short Term Color Memory II: This film test is similar to variable 5. It differs in that it marks the color to be remembered and identified by following the array with a horizontal color bar in screen center. The Ss are then to indicate the position occupied by the color, rather than the color occupying a designated position, as in variable 5.

8. Short Term Object Memory I: A film test in which Ss are first shown a stimulus pool of nine common object photographs (camera, binoculars, boat, car, shoe, pistol, drill, chair, and pipe). In each item, six of the photographs are presented in a 2 by 3 array, appearing either for 4, 8, or 12 film frames. The 54 items, total, include 18 items at each of the three exposure durations and thus, three subtests. After the array disappears, there are two blank frames and then an empty rectangular marker appears in one of the six array positions and remains on the screen for ten frames. The Ss are to mark on their answer sheet the name of the object which appeared in the marked position. Twelve seconds are allotted for responding to each item.

9. Successive Perception III: For each item in this film test the examinee must identify and name the picture of some common object. A series of eight overlay mats are used to block certain portions of the photograph. Thirty-two cells (1/8 of the total cells) were randomly removed from each mat which represents a 16 x

16 grid. Since there is a mat change every 42 msecs, the examinee never sees the complete photograph. However, over one second all details of the photo appear three times (Seibert and Snow, 1965 , p. 29).

10. Picture Identification: A film test of 20 items, with each item presenting a still photograph of some common object partially obscured behind overlaying white strips. The photographs are halftone black and white and each appears on the screen for twenty seconds. The task is similar to that of the Street Gestalt Completion test and it requires Ss to identify the object and to record its name.

11. Successive Perception IV: The difference between this test and test 9 is that the mat changes every 625 msecs. The examinee is required to identify the common object by writing its name (Seibert and Snow, 1965 , pp. 29, 30).

12. Picture Memory Span: This film test employs a pool of 22 common object photographs and in each item it presents four to ten of these pictures, as in a customary memory span test. Each photograph is on the screen for one-half second, with one-sixth second between adjacent photographs. Response time is adjusted in accordance with the number of photographs in the series. The Ss are to record in correct order the names of the objects in each series.

13. Short Term Visual Memory II: A film test of 64 items which includes eight eight-item subtests. In each item an eight letter, 2 by 4 array is presented tachistoscopically (i.e., for about 31 milliseconds) in screen center. A black circle marker appears to mark on one of the eight array positions and Ss are to record the letter occupying the designated position. The vertical bar marker may precede the array by 52 milliseconds or may follow it by 10, 94, 177, 260, 344, 428, or 510 milliseconds.

14. Short Term Visual Memory III: This film test is highly similar to variable 13, above, except that it employs two markers to designate the same array position in each test item. Simultaneously with each 2 by 4 array, a black vertical bar marker appears. Then, at intervals identical with those for variable 9, a circle marker also appears.

15. Position Recall I: This printed test presents twelve drawings in a 3 by 4 array on each of four pages. The Ss are allowed 1 1/2 minutes to study each page. Later, the same drawings are shown randomly ordered on each page and the Ss must indicate the position each drawing occupied on the original study page.

16. Position Recall II: This printed test is a continuation based on variable 15, above. Here, though, the Ss must indicate for each drawing whether it first appeared on the first, second, third, or fourth study page.

17. Wide Range Vocabulary: A printed test of knowledge of word meanings. It is a five-choice synonym test having items ranging from very easy to very difficult. Each part consists of 24 items. Six minutes are allotted for each of the two parts (French, Ekstrom, and Price, 1963, p. 46).

18. Advanced Vocabulary: A printed test in which work is presented and S must choose a synonym from among five alternatives. Each of the two parts includes 18 rather difficult items. Four minutes are allowed for each part. Both parts were used for the present study (French, Ekstrom, and Price, 1963, p. 46).

19. Color Form Recognition: This is also an adaptation of a test by Christal, entitled Color Form-Word Association. It presents a list of colored geometric forms for memorization. Afterward, S is given a larger list of colored forms from which he must recognize and select those presented previously.

APPENDIX D

Intercorrelation Matrix of Ten Stimulus Characteristic Variables and Three Criteria Variables

	1	2	3	4	5	6	7	8	9	10	11	12
2	-.04											
3	-.17	.08										
4	.29	.01	-.08									
5	.64	-.08	-.09	.15								
6	.13	.12	.11	-.02	.13							
7	.13	.02	.01	.15	-.02	.20						
8	-.08	.07	-.02	.20	.23	-.01	.04					
9	.10	.03	.15	.53	.19	-.15	-.01	.12				
10	.23	-.04	-.05	.52	.11	-.20	.15	.15	-.01			
11	.04	-.03	.07	-.07	.15	.05	-.30	.09	.11	-.16		
12	.04	.01	.01	-.05	.11	-.02	-.28	.10	.06	-.12	.94	
13	.76	-.03	-.16	.36	.66	.05	.13	.51	.22	.33	.22	.18

APPENDIX E

1. Total Frames: The total number of frames in the "frame sequence" associated with a criterion test item. A frame sequence consists of all the frames intended to instruct the answer to the test item. Identification of these "teaching" frames was necessarily subjective and was guided by such cues as the appearance of the key term in a frame, particularly as a response, and the set to which readers are referred for review.

2. Review Frames: The total number of frames within a frame sequence separated from initial learning frames by five or more consecutive frames unrelated to the test item.

3. Key Term as Response: The number of times that the frame sequence requires the learner to supply the key term wholly or in large part.

4. Maximum Words per Frame: The number of words contained in the frame with the most words.

5. Percent of Responses Occurring in First Third of a Frame: The percentage of responses in the frame sequence which are required within the first third of a frame's words.

6. Intentional Sets: The total number of sets containing frames intended to teach the key term.

7. Application Frames: The ratio of applications, illustrations, examples within a frame sequence to the number of frames.

8. Number of Responses per Frame: The number of responses per frame within a frame sequence. A multi-word response was considered as one response.

9. Words per Sentence: The number of words per sentence within a frame sequence.

10. Sentences per Frame: The number of sentences per frame within a frame sequence.